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LARGE NONDEFENSE R&D PROJECTS
IN THE BUDGET: 1980-1996

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PREFACE

The Congress has approved the initial funding of several large nondefense research and development projects that are expected to cost $23 billion in the period 1992 through 1996. The large size of these projects has caused some concern as to whether they may be funded at the expense of other R&D activities in the years ahead. At the request of the Senate Committee on the Budget, the Congressional Budget Office (CBO) undertook to examine the funding of large nondefense R&D projects in the past in an effort to determine whether such "megaprojects" tend to crowd out federal spending on smaller R&D programs and on other government-sponsored activities. In keeping with CBO's mandate to provide nonpartisan analysis, the paper makes no recommendations.

David Moore and Philip Webre of CBO's Natural Resources and Commerce Division wrote the paper under the supervision of Elliot Schwartz. The budget staffs of the Department of Energy and the National Science Foundation provided valuable assistance in compiling R&D project budgetary histories and forecasts. Thomas Lutton of CBO provided computational assistance. The authors wish to thank William Boesman, Daryl Chubin, Peter Fontaine, Leon Lederman, Frances Lussier, and other reviewers for their valuable suggestions.

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Director

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SUMMARY

The Administration's 1992 budget request calls for increases in federal support for nondefense research and development (R&D), and for the agencies and budget areas that fund these activities. These expenditures include funding for the National Aeronautic and Space Administration's space station and its Earth Observation System, and the Department of Energy's Superconducting Super Collider. Concern has arisen that these and other large R&D projects will be funded at the expense of smaller-scale activities, including many projects initiated by single investigators.

This study examines the budgetary history of large nondefense R&D projects during the 1980s, as a background to the Administration's proposal for the 1990s. Three specific questions are addressed:

- Are large nondefense science and technology projects currently consuming more budgetary resources, in either absolute or relative terms, than during the 1980s?

- Under the Administration's program, will large nondefense science and technology programs increase their share of science and other spending aggregates relative to current levels and to the trend during the 1980s?

- Are large nondefense science and technology projects funded at the expense of all other R&D spending (including "little science") or other types of spending?

BACKGROUND

Advances at the frontiers of science and technology have required ever more complex and expensive facilities, instruments, and experiments. The proliferation of these projects in the federal budget has raised a number of issues. Large R&D projects are expensive. Outlays on the space station and the Earth Observation System (EOS) could run to $35 billion and $17 billion, respectively, before the year 2000. The Superconducting Super Collider could require an investment of between $8 billion and $12 billion by the same year. Cost, of course, is not the only standard by which to judge an investment. Supporters of these large R&D projects believe they will deliver benefits that justify the expense, although not all share their confidence.

Large R&D projects are also risky. Their costs of development and operation are difficult to estimate, and it is also difficult to be certain of the capabilities of a system once developed, and the importance of its mission. Failure in a large R&D project may cause serious setbacks to scientific or technical projects that depended on its success. The very riskiness of large R&D projects, however, is an argument for federal support, since the government is the only institution able to bear the cost and the risk of these ventures.

Finally, some critics of large R&D projects raise a political concern: such projects, particularly in their development and construction phases, provide income for localities and businesses. Also, large projects increase the budgets of the federal agencies that sponsor them. These factors are not particularly important so long as they do not intrude heavily on the scientific and technical criteria used to make decisions about the mix of large and small projects. But if cost overruns or budget constraints require choosing between large and small projects, it would be against the national interest to support large projects at the expense of small ones for nonscientific and nontechnical reasons.

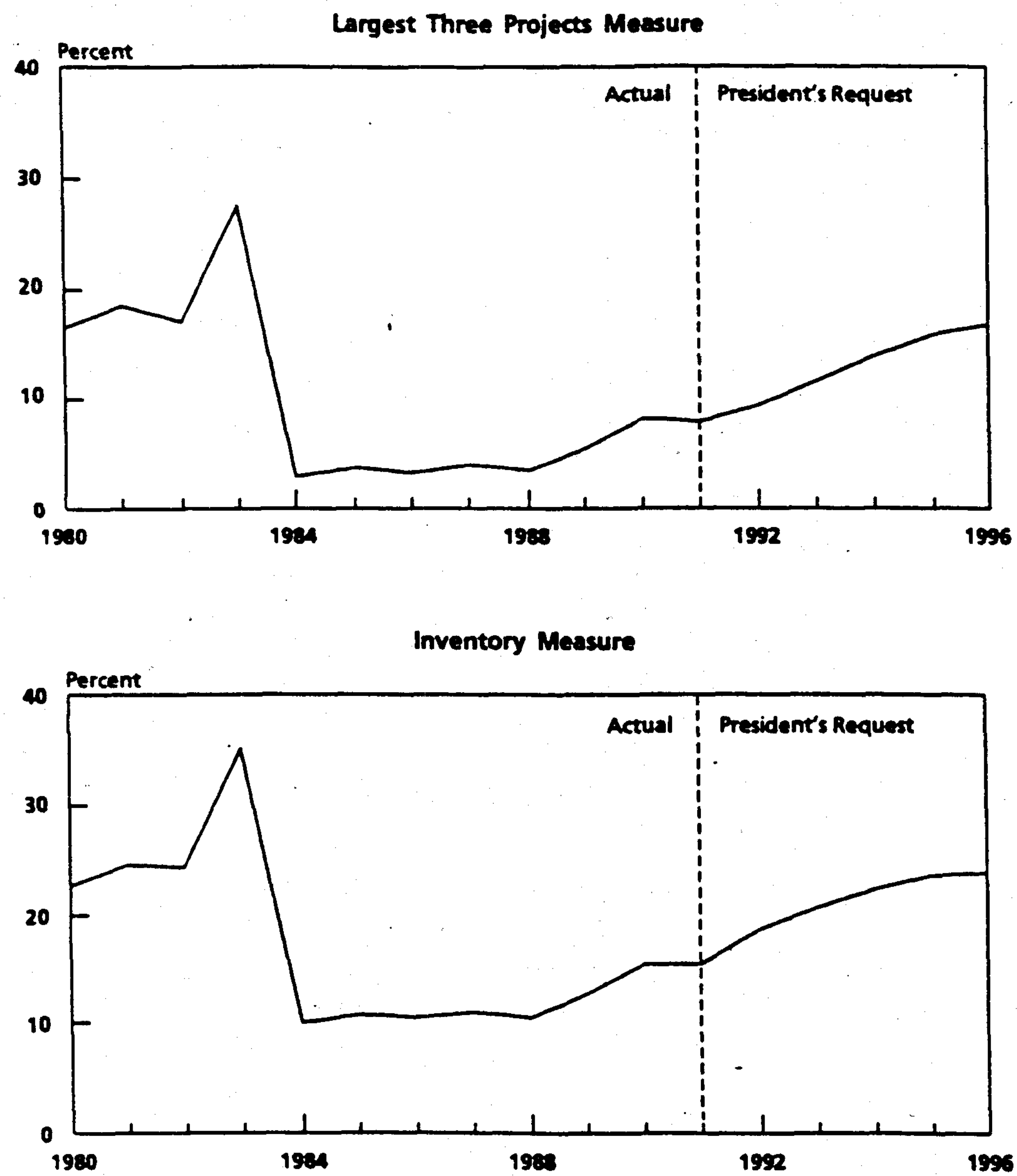
TRENDS IN SPENDING FOR LARGE R&D PROJECTS

After examining a variety of budgetary measures, CBO finds that the Administration's plan would increase the share of funding devoted to large nondefense R&D projects to levels not seen since the early 1980s. As Summary Figure 1 shows, the share of total nondefense R&D funding devoted to large nondefense R&D projects peaked sharply in the early 1980s, then fell in 1984 when spending for the development of the space shuttle ended. The share of nondefense R&D spending accounted for by an inventory of 80 large R&D projects and facilities rose from around 10 percent in the mid 1980s to over 15 percent by 1991 (the lower panel in Summary Figure 1). If the Administration's program was enacted, the share of large R&D projects would rise even more during the first half of the 1990s to 22 percent by 1996. The three largest projects in the inventory alone would double their share of nondefense R&D spending from the current level of 8 percent to 15 percent under the Administration's plan. The three largest projects would also increase their share of all domestic discretionary spending from 1.1 percent in 1990 to 2.8 percent by 1996.

The Administration's proposal calls for increases in overall R&D spending large enough to maintain the shares going to both "big science" and "little science." This approach would avoid the situation of the early 1980s when total spending in R&D-related budget functions remained flat or declined while large projects consumed a greater portion of the total.

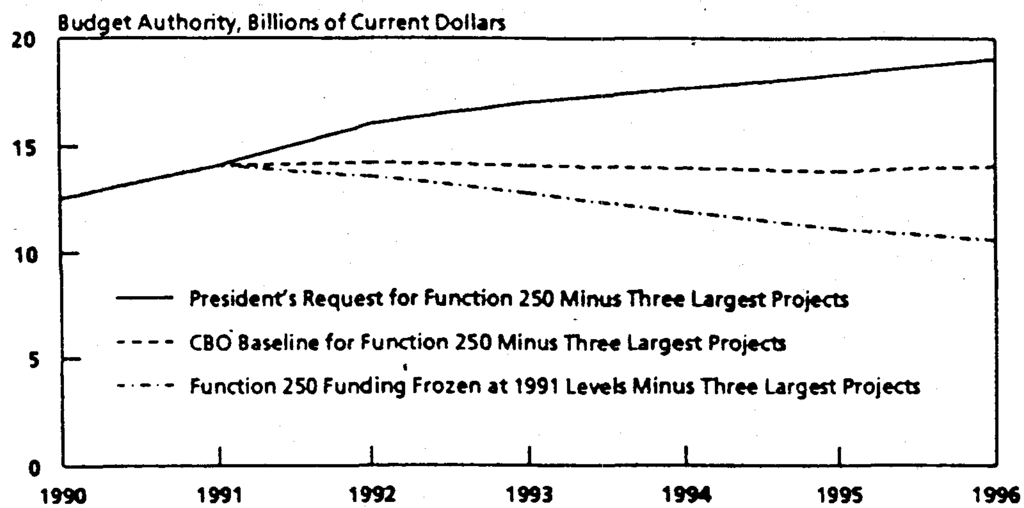
If the cost of large projects increases, or overall funding for general science and space turns out to be less than requested, the Congress could confront a choice between funding large R&D projects and other science and technology spending. Summary Figure 2 shows what could happen to spending on other science and technology if the very largest projects were funded as the Administration proposes, but the Congress placed constraints on overall space and science spending. If the largest three projects were funded as proposed and budget function 250 was permitted only to keep up with inflation--CBO's baseline projection--funds available to support other science and technology spending would be 25 percent below the

Summary Figure 1.
Spending on Large Research and Development Projects as a Percentage of Spending on All Nondefense Research and Development, Fiscal Years 1980-1996



SOURCE: Congressional Budget Office.

Summary Figure 2.
Alternative Projections of Spending for General Science, Space, and Technology Minus the President's Request for the Three Largest Projects, 1990-1996



SOURCE: Congressional Budget Office.

NOTE: Function 250 covers spending on general science, space, and technology.

Administration's plan. If spending for general science, space and technology (function 250) was frozen at the 1991 level through 1996, and the largest projects permitted to proceed as planned, other science spending would be reduced by 45 percent relative to the levels the Administration proposed. The National Science Foundation, a prominent source of funding for small R&D, would certainly be among the agencies considered for reductions from the Administration's plan under either scenario.

BUDGETARY OPTIONS

Current knowledge about the relative benefits of large projects as compared with smaller ones is not sufficient to provide much guidance as to how funds ought to be allocated between these types of activities. To keep better informed, the Congress may wish to initiate a biennial "cross-cutting review" of science and technology spending as suggested recently by the Office of Technology Assessment. The review would compare such spending by all agencies with broad national objectives and specific technological goals to see whether the distribution of current spending, including that between large and small R&D efforts, best meets these objectives and goals. Such a review could be useful even though it would partly duplicate the annual budget review several Congressional committees already conduct.

The Congress could also try to balance spending for large projects and spending for small projects by using multiyear appropriations and arbitrary annual spending caps. Multiyear appropriations might be effective in controlling the total cost of big projects by allowing agencies to proceed on an optimal schedule without tailoring their programs to fit annual budgetary requirements. But multiyear appropriations will not be effective in controlling cost if technical uncertainties lead to cost overruns. In defense programs, multiyear appropriations have been more successful in procurement projects than in developing technology.

Arbitrary annual caps could be placed on spending for large projects, set at levels that would assure adequate funds for other science spending. Caps offer the advantage of being in current use and easily understood, but they would raise the total costs of big projects.

Canceling one or more of the largest projects could offer immediate and sustained budgetary savings. Canceling the space station program, for example, could free up between $2.0 billion and $2.6 billion each year for other space and science projects, if Congress chose to appropriate funds for these purposes rather than other federal priorities.

Finally, the Congress may wish to pursue partnerships with other countries in large science and technology projects on a more equal basis than at present. Foreign partners would have more say in managing such projects in exchange for carrying a larger share of the costs. U. S. contractors would have to give up some of the procurement business, however. Multiyear appropriations could help to make more equal international partnerships effective. Thus, a secondary cost of these ventures could be the loss of Congressional oversight and funding flexibility granted by annual appropriations.

CHAPTER I
INTRODUCTION

Over the last several years, the Congress has been asked to fund a set of "big science" programs that will cost billions of dollars. These are large nondefense research and development projects in areas such as space exploration, high-energy physics, and geoscience. Outlays on such projects would reach a peak in the first half of the 1990s, at a time when budgetary constraints will be severe. This paper has assembled data to show the trend in funding large research and development (R&D) projects during recent years, together with projections of current plans through 1996. The aim is to assess the budgetary implications of such spending. The paper reviews only briefly more fundamental questions about the productivity of federal spending for large R&D projects as opposed to other R&D projects, other federal spending, or deficit reduction.[1]

The paper poses and seeks to answer three interrelated questions:

- Are large nondefense R&D projects currently consuming more budgetary resources, in either absolute or relative terms, than during the 1980s?

- Under the Administration's program as presented in the 1992 budget, will the share of spending devoted to large nondefense R&D projects increase relative to that of other programs?

- Are large nondefense R&D projects being funded at the expense of other science and technology programs (including "little science") or of other categories of spending?

CIVILIAN SCIENCE AND TECHNOLOGY IN THE FEDERAL BUDGET

The President's budgetary proposals for 1992 emphasize spending for civilian (that is, nondefense) science and technology. This emphasis is reflected in the proposed increases for the budget functions supporting civilian science spending and the major agencies that sponsor such programs, and in the cross-cutting budgetary aggregate of civilian research and development. Proposed nominal increases for civilian R&D include 9 percent for basic research and 10 percent for applied research and development. Another significant highlight of the budget is the increases it proposes for several specific projects and facilities: 7 percent for the space station, 82 percent for the Earth Observation System (EOS), 120 percent for the Superconducting Super Collider (SSC), and 25 percent for the Human Genome Project.

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1. The Office of Technology Assessment, in its Federally Funded Research: Decisions for a Decade (May 1991), poses a set of more fundamental questions than those addressed in this report.

In 1991 total federal support for all R&D was $67 billion, with nondefense programs accounting for $28 billion of the total.[2] Federally supported R&D represented about 45 percent of the national total. The federal role is even more pronounced when only basic research is considered, where federal support accounts for 70 percent of the national total.[3] The major components of federal spending for civilian R&D for 1991 are shown in Table 1. Spending is broken down by agency in Table 2.

The historical trend in federal spending for civilian R&D has a roller-coaster pattern, generated in part by the rise and decline of funding for large R&D projects (see Figure 1). The Apollo program accounted for a rise in federal R&D spending in the 1960s and its subsequent fall through the early 1970s. Increased spending for health research, for developing the space shuttle, and for energy programs pushed up civilian R&D through the early 1980s. Changing energy polices brought a decline in the first half of the 1980s, but since then increases in spending for space, general science, and health research have driven total civilian R&D up sharply.[4]

Federal support of science is based on a widely accepted rationale. Scientific knowledge is recognized to be a public good that many users can consume without diminishing its worth to other users. The private economy characteristically produces too little of this type of good. Government spending on pure science programs helps to correct this failing of the private economy by generating new scientific knowledge; it also assures the country's future scientific capability by investing in new facilities and training new scientists. Federal programs and policies that encourage private R&D likewise work to narrow the gap between the value to society of scientific activity and its value in the private market. Without these incentives, private firms might invest too little in R&D from society's point of view since the benefits of R&D do not always show up in the balance sheet. While this rationale for federal support is generally accepted, it offers little guidance as to how much the government should spend, and on what.

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2. Note that different data series use slightly different definitions because they are collected from different surveys for different purposes. Consequently, there may be slight discrepancies between data series. For instance, federal R&D spending for 1990 totals $63.8 billion, $66.08 billion, $68.5 billion, or $69.2 billion depending on the data series. (See Appendix for fuller discussion of data.)

3. For a review of the trends in federal support for research and development see Congressional Budget Office, *How Federal Spending for Infrastructure and Other Public Investments Affects the Economy (June 1991)*, chap. 4 and David C. Mowery and Nathan Rosenberg, *Technology and the Pursuit of Economic Growth* (Cambridge: Cambridge University Press, 1989), chapter 6.

4. Congressional Budget Office, *How Federal Spending for Infrastructure and Other Public Investments Affects the Economy* (June 1991).

TABLE 1. MAJOR COMPONENTS OF FEDERAL FUNDING FOR CIVILIAN R&D IN 1991 (In billions of dollars)

Health	9.8
Space	5.2
Energy	3.2
General Science	3.1
All Other	7.1
Total	28.4

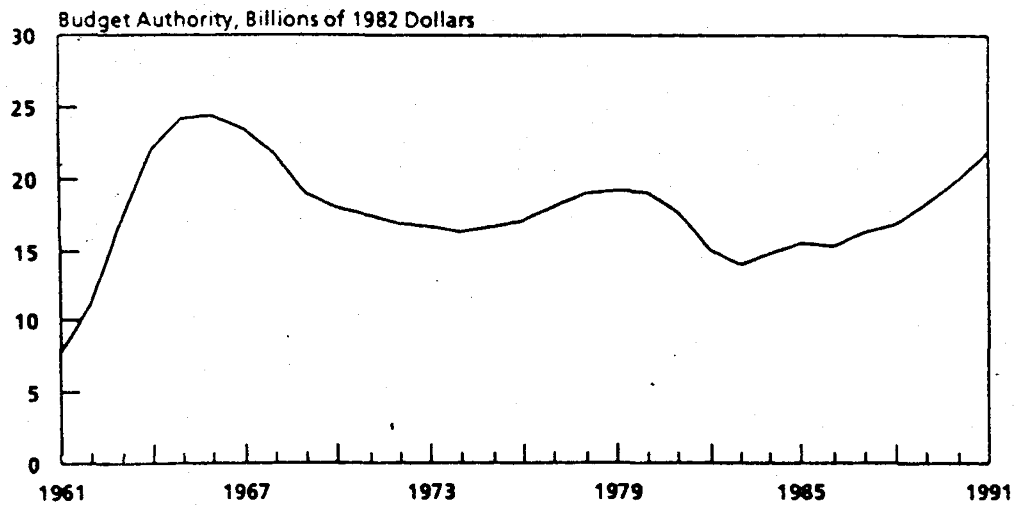
SOURCE: Congressional Budget Office based on American Association for the Advancement of Science, AAAS Report IVI Research and Development FY 1992, (1991) Table 1-4, p. 48

TABLE 2. R&D IN SELECTED AGENCIES FOR 1991 (In billions of dollars)

National Aeronautics and Space Administration	8.1
National Institutes of Health	7.9
Department of Energy	4.2
National Science Foundation	1.9
Other Health and Human Services	1.6
Department of Agriculture	1.4
Environmental Protection Agency	0.5
Department of Commerce	0.5
Geological Survey	0.4
Department of Education	0.2
Bureau of Mines	0.1
All Other	1.7

SOURCE: Congressional Budget Office based on American Association for the Advancement of Science, AAAS Report XVI Research and Development FY 1992, (1991) Table 1-7, p. 52.

Figure 1.
Funding for Nondefense Research and Development, 1961-1991



SOURCE: Congressional Budget Office based on National Science Foundation, *Federal R&D Funding by Budget Function* (various years) and National Science Foundation "Federal Funds for Research and Development; Detailed Historical Tables: Fiscal Years 1955-1990."

NOTE: Before 1979, data are in obligations.

LARGE AND SMALL R&D PROJECTS IN THE BUDGET

Many federally funded R&D projects tend to be very large. Their size is a reflection of scientific and technical progress: In many areas, progress requires increasingly expensive equipment and facilities as the advances permitted by the previous generation of equipment are exhausted. The federal government can undertake large projects because it has the ability to bear the risks and costs of such investments. At the same time, scientific and technical progress is continually opening new fields of inquiry that are arguably candidates for federal support. A conflict potentially arises between federal support of continuing progress in specific fields of inquiry and the equally important need to maintain a diversified science and technology base.

From a budgetary perspective, a large R&D project characteristically requires expensive and large-scale equipment that needs several years of funding to develop and build, and thereafter many years of operational support to deliver new scientific results. Large R&D projects typically begin with investment in engineering and construction activities. During this "ramp up" period, funding requirements increase rapidly. The benefits of this phase of activity flow to the local areas and contractors involved in the project. The major contribution of large R&D projects to scientific knowledge and technical achievement occurs later, during the operational phase. These projects typically have a core research agenda that the federal government develops and oversees.

In contrast, small R&D projects or "little science" tend to be initiated and conducted by a single investigator or a small team. The scientist plans them and the government funds them in a way that allows the investigator latitude as to the specific questions investigated and the methods employed. Small R&D projects typically use facilities and equipment that are currently available and seek to achieve results in the short term.

Federal support for small R&D provides the bulk of public funding of university-based research. Federal agencies supporting small R&D projects generally spend a high proportion of their funds on R&D conducted in universities. For example, in 1991 the National Science Foundation spent 71 percent of its R&D funds on university-conducted research; the corresponding figure for the National Institutes of Health was 54 percent. The National Aeronautics and Space Administration and the Department of Energy, which are the primary funders of large R&D projects, spent only 7 percent and 9 percent of their respective funds on university-conducted research in the same year.[5]

Concern about the relation between large R&D projects and smaller efforts arises on several fronts. Large R&D projects are expensive, both to build and to operate. In an era of tight budgets, committing resources to one program inevitably

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5. American Association for the Advancement of Science, AAA Report XVI: Research and Development FY. 1992 (1991), Table 1-7 and Table 1-9.

means that less will be available for others, including the smaller R&D efforts that maintain universities' scientific and technical base. If a large project is funded at the expense of many smaller ones, the large effort must deliver commensurately large benefits if it is to be justified as a sound public investment. The benefits large projects deliver beyond scientific and technical results may be decisive in this calculation. For example, large projects help to maintain the leading role of the United States in science and technology, and draw the attention of young people to careers in those fields--benefits that are difficult to measure.

Large R&D projects are risky. Their costs, capabilities, and schedules are subject to considerable uncertainty. For example, the four precursors of the proposed Superconducting Super Collider built in the 1980s exceeded their initial cost estimates by almost half, even after adjusting for inflation.[6] The ultimate capabilities of large R&D projects may be as uncertain as their cost. For example, the space shuttle was developed with the expectation of flying almost 60 times a year rather than the current flight rate of 6 to 8 launches each year. The long periods of time necessary to design, develop, and build large R&D projects expose them to the risk of technical obsolescence. While the possibility of failure is intrinsic to any risky scientific or technical enterprise, with large projects the cost is higher. However, the riskiness of large R&D projects also provides an argument for federal support: only the government is capable of bearing both the cost of creating large R&D projects and the risk of their failure.

Cost overruns are particularly vexing for large projects. Unanticipated funding demands force the Executive branch and the Congress to choose between several alternatives: funding the overrun, reducing the project's capabilities, delaying its completion, or perhaps combining all three. A decision to fund the overrun may force a decrease in spending for other R&D purposes, not as a consequence of well-formulated plans or policies but under the immediate pressure of meeting the annual budget constraint. The alternatives of reducing the project's capabilities or delaying it will exact their own price. The project's potential benefits will be decreased if its capabilities are reduced. If the project is delayed, total costs are likely to increase because the fixed costs of development will be incurred longer than necessary. Moreover, delay in achieving benefits also represents a cost, although the budget does not show it.

The Congress could avoid the potential conflict between funding for large projects and funding for other scientific and technical efforts by increasing overall spending on science and technology. Under the Budget Enforcement Act, however, caps have been placed on discretionary spending. The position of several large R&D projects in their "ramp up" phase, together with the spending caps by the Budget Enforcement Act created, may present the political system with essentially the same choices as a cost overrun: pay and crowd out other federal priorities, reduce

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6. Congressional Budget Office, Risks and Benefits of Building the Superconducting Super Collider (October 1988), pp. 44 - 48.

capabilities and future benefits, or delay projects and increase their total costs while deferring scientific and technical benefits.

APPROACHES TO MEASURING THE BUDGETARY IMPLICATIONS OF LARGE R&D PROJECTS

To what extent is concern about the productivity of large projects justified? Do large projects tend to crowd out smaller efforts? This paper develops measures that contribute to answering these questions by examining the extent to which large R&D projects dominate federal spending on both large and small R&D projects.

Yet, even this limited statement of the question is fraught with problems of definition and measurement. Stating the issue as big science versus small science gives the misleading impression that all large R&D projects are scientific in nature. They are not. Some large R&D projects focus on exploration or technology development rather than creating new scientific knowledge. Nevertheless, it would also be misleading to treat the R&D phases of large projects like the space shuttle or the proposed space station as federal activities with no special budgetary connection to science. Science projects, strictly defined, share the same agencies, budget functions, and appropriations jurisdictions with these large projects. For this reason, some of the measures of "big science" developed in the paper include all large civilian R&D projects--whether strictly science projects or not--so that the relation between spending for these purposes and spending on other science and technology can be explored.

Two additional questions concern the definition of "large R&D" and the relation between large and small projects in the budget. The paper makes no definitive claim to having a precise measure of large R&D. Instead, it presents several alternative budgetary measures of large R&D, none of which is completely satisfactory. The strategy of the paper is to apply different measures and look for common (or differing) trends.

The relationship between large and small R&D projects in the budget is problematic. Recently, concern has been expressed that large projects crowd out smaller ones particularly when budgets are tight overall. An alternative thesis is that large projects and small projects stand or fall together, with large projects often the critical ingredient in attracting attention to science and technology in general. A third theory might hold that the relationship between large and small R&D projects is not constant, but rather has changed over time. This paper makes no definitive statement about the past, since it cannot be stated with certainty that smaller projects would have fared better, for example, had NASA not embarked on its shuttle project.

CHAPTER II
MEASURING THE BUDGETARY EFFECTS OF LARGE R&D PROJECTS

Large R&D projects concentrate resources on developing and building sizeable facilities and instruments. During the operational phase of a project, institutions are created that govern the use of the facility or instruments, and in some cases steer an entire field of scientific or technical activity. It is difficult to capture all these aspects of large R&D projects in a single measure. Consequently, this chapter develops alternative measures of spending for large R&D projects. Three of the measures focus on construction and hardware. A fourth is broader, and includes all of the spending in fields of science and technology that are dominated by expensive instruments and facilities.

Standing alone, each of these measures is subject to conceptual problems, or to specific questions about why a particular project or group of projects was included or excluded. Alternative measures correct for the limitations of each. Also, they make the composite picture more accurate by establishing where the trend in each measure coincides with or differs from the other measures.

The impact of large R&D projects on the federal budget is examined by comparing the four measures of spending for large R&D projects with several aggregates of science and technology spending aggregates--for example, the share of large R&D projects in all civilian R&D. Finally, the four measures of spending for large R&D projects are compared with a time series of domestic discretionary spending.

MEASURES OF SPENDING FOR LARGE R&D PROJECTS IN THE BUDGET

The four different budgetary measures of large R&D projects are:

- An inventory of projects that includes all those defined as large by arbitrary criteria;
- A "largest projects" measure that includes only the three R&D projects receiving the most funding in a given year;
- A "fields of research" measure including all spending in scientific and technical fields dominated by large instruments;
- An "R&D structures" measure that includes only plant and equipment spending.

The four measures all rely, for the most part, on readily available sources of data. Table 3 presents the dollar value of each measure for 1980 through 1996. Three of the measures are in terms of budget authority, which is most directly under